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REPORT NAEC-91-7983

LEVEL II

SYSTEM SAFETY PROGRAM REPORT MK 1 MOD 0 LSO HUD CONSOLE SYSTEM

Ship and Shore Installations Engineering Department
Naval Air Engineering Center
Lakehurst, New Jersey 08733

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Technical Report

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Prepared for

Commanding Officer
Naval Air Engineering Center
Lakehurst, New Jersey 08733

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SYSTEM SAFETY PROGRAM REPORT
MK 1 MOD 0 LSO HUD CONSOLE SYSTEM

Prepared by: J. Glenn
J. Glenn
91133 Section

Reviewed by: P. More, Jr.
P. More, Jr.
91133 Section Supervisor

Approved by: F. B. Boice
F. B. Boice
Engineering Officer

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The MK 1 MOD 0 LSO HUD Console System provides aircraft recovery information to the Landing Signal Officer aboard aircraft carriers. This report documents the System Safety Program accomplishments (safety analysis, verification, and test) and assesses system safety.		

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SUMMARY

A. SAFETY PROGRAM. The system safety program for the MK 1 MOD 0 LSO HUD Console System consists of the following elements:

1. Hazards/failure modes and effects analysis to identify personnel hazards and equipment failure modes.
2. Safety testing and verification to evaluate and compare analysis results with operational hardware.
3. Corrective actions implemented and planned for implementation to eliminate or control the more severe hazards.

B. RESULTS AND RECOMMENDATIONS

1. Appendix A summarizes the more severe hazards identified by analysis and lists planned corrective actions where appropriate.
2. Implementation of planned corrective actions will provide reasonable assurance that the LSO HUD Console System will be operated and maintained in safety.
3. Completion of the safety test and verification phase for the Hydraulic Lifting Unit Subsystem will provide the final assurance that overall safety requirements have been met.

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I. INTRODUCTION

A. GENERAL: This report documents the System Safety Program as it applies to the MK1 MOD 0 LSO (Landing Signal Officer) HUD (Heads-Up-Display) Console System. The safety program is in general accordance with MIL-STD-882A (reference (a)) and the Safety Engineering Plan for the LSO HUD Console System (reference (b)).

B. ACCOMPLISHMENTS: Safety program accomplishments include:

1. H/FMEA (Hazards/Failure Modes and Effects Analysis) on the entire LSO HUD Console System (reference (c)).

2. Safety testing and verification of the display subsystem at the Pacific Missile Test Center.

3. Limited safety verification of the Hydraulic Lifting Unit Subsystem at the Naval Air Engineering Center.

4. Implementation of corrective actions to eliminate or control several hazards identified in the H/FMEA.

5. Planned corrective actions to eliminate or control the remaining verified Category I and II hazards identified in the H/FMEA.

C. PRINCIPLE AGENTS: The principle agents involved with administering the LSO HUD Console System Safety Program are:

1. NAVAIRSYSCOM (Naval Air Systems Command): Acquisition Management, Code 5512D.

2. NAVAIRENGCEN (Naval Air Engineering Center):

a. Program Management, Code 91118

b. System Design Cognizance, Code 91132

c. Safety Coordination, Code 91133

d. Safety Test and Evaluation, Code 94

Ref: (a) MIL-STD-882A; System Safety Program Requirements, 28 June 1977

(b) NAVAIRENGCEN-ENG-7932; Safety Engineering Plan, Landing Signal Officer (LSO) Heads-Up-Display (HUD) Console MK1 MOD 0, 28 March 1977

(c) NAVAIRENGCEN Report NAEC 91-7958; Hazards/Failure Modes and Effects Analysis, MK 1 MOD 0 LSO HUD Console System, 24 March 1980

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3. PACMISTESTCEN (Pacific Missile Test Center): Display Subsystem final development and safety test and evaluation Code 1170.

4. Ketron, Inc, Wayne Pennsylvania: Hazards/failure modes and effects analysis.

II. SYSTEM DESCRIPTION

A. The LSO HUD Console System is located at the LSO's (Landing Signal Officer) Work Station on the aircraft carrier.

B. The mission of the LSO Work Station Facility is to serve as a focal point for recovery information display and communications required for flight-path guidance control coordination between the LSO and pilot of the landing aircraft. The MK 1 MOD 0 LSO HUD Console System has been developed as part of an effort to increase the accessibility and visibility of information displays and communications facilities in the LSO Work Station to permit more rapid perception and response by the LSO to flight-path deviations under all weather conditions to improve the safety of recovery operations.

C. The LSO HUD Console System consists of a Display Subsystem and a Hydraulic Lifting Unit Subsystem.

1. The Display Subsystem receives data signals from various existing shipboard systems for processing and display in the LSO HUD Console. Calibration, testing, and troubleshooting of display circuits is facilitated with a piece of portable special purpose test equipment. Those systems providing inputs to the HUD console include:

- a. SPN-42 Radar (Automatic Carrier Landing System)
- b. SPN-44 Radar
- c. ILARTS (Integrated Launch and Recovery Television Surveillance) or PLAT (Pilot Landing Aid Television) System
- d. FLOLS (Fresnel Lens Optical Landing System)/Arresting Gear Cross-Check System
- e. Landing Area Status System
- f. Ship's Wind Measuring System
- g. Ship's 21MC Intercom System
- h. MOVLAS (Manually-Operated Visual Landing Aid System) MK 1, MOD 2
- i. FLOLS MK 6 MOD 3 or MK 6 MOD 2 with Trim/Harmonization Computer
- j. FLOLS Wave-Off Subsystem

2. The Hydraulic Lifting Unit Subsystem provides a means for raising the HUD Console to an adjustable height to accommodate viewing by an LSO standing on the LSO Platform. It also provides for lowering the HUD Console to an unobstructing level below the flight deck into a storage enclosure. Raising and lowering control is accomplished within the LSO Work Station, and control circuit interlocks guard against retracting the Console when it is misaligned with its storage enclosure or raising the Console when the storage enclosure lid is down.

III. SAFETY ANALYSIS

A. GENERAL: The H/FMEA of the LSO HUD Console System (see reference (c)) was performed by Ketron, Inc. to identify personnel hazards and singlepoint failure modes that could result in:

1. Personnel injury or death;
2. Equipment damage or loss;
3. System mission impairment or loss.

Design improvement recommendations were made to prevent or greatly reduce the likelihood of the above undesirable events.

B. ANALYSIS FORMAT: Format for the H/FMEA is shown in Figure 1. Hazard level and probability classification are listed at the bottom of Figure 1. Hazard level is further defined as follows:

1. Category I - Catastrophic: Will cause death or severe injury to personnel or system loss.
2. Category II - Critical: Will cause personnel injury or major system damage, or will require immediate corrective action for personnel or system survival.
3. Category III - Marginal: Can be counteracted or controlled without injury to personnel or major system change.
4. Category IV - Negligible: Will not result in personnel injury or system damage.

C. ANALYSIS SUMMARY AND HAZARD LEVEL REASSIGNMENT

1. The H/FMEA has been reviewed for accuracy and validity by both the Naval Air Engineering Center and the Pacific Missile Test Center, Point Mugu, California. The hazards identified as Category I or II in the H/FMEA have been summarized and evaluated in terms of corrective action in Appendix A of this report. Appendix A contains:

- a. Failure modes, hazards and their effects (Category I and II only).
- b. Design changes and compensating provisions which have been incorporated in the LSO HUD Console System as a result of the analysis.
- c. Proposed design changes and compensating provisions.
- d. Rationale for taking no action, where appropriate.

2. In some areas the H/FMEA has been found inaccurate and in need of hazard level reassignment:

- a. The primary function of the LSO-HUD Console System is the enhancement of signals and cues already available to the LSO. Therefore, the failure

FAILURE MODES & EFFECTS ANALYSIS - SYSTEM SAFETY ANALYSIS HAZARD ANALYSIS

TABLE: _____

NAME: (Sub-system) _____

DWG. NO./REV.: _____

Page ____ of ____

ITEM NO.	ITEM DESCRIPTION (COMPONENT, MODE OF OPERATION, FUNCTION)	HAZARDOUS- FUNCTIONAL FAILURE MODE (HAZARD RELEASE MECHANISM)	EFFECT ON:						FAILURE - HAZARD			COMMENTS; RECOMMENDATIONS; COMPENSATING PROVISIONS (ACCIDENT PREVENTION MEASURES; SAFETY CONTROLS)
			PERSONNEL	SYSTEM	MISSION	LOSS	POTENTIAL	LOSS	DETECTABLE BY OPERATOR?	CLASSIFICATION (HAZARD LEVEL)	PROBABILITY OF OCCURRENCE	
(1)	(2)	(3)	LIVES	INJURY	LOSS	DAMAGE	LOSS	POTENTIAL	(10)	(11)	(12)	(13)

NOTE: Hazard Level, Column 11, per MIL-STD-882A, para. 5.4.3.1 (I-Catastrophic; II-Critical; III-Marginal; IV-Negligible);
Hazard Probability, Column 12, per MIL-STD-882A, para. 5.4.3.2 (A-Frequent; B-Reasonably Probable; C-Occasional; D-Remote; E-Extremely Improbable;
F-Impossible)

FIGURE 1

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of part or all of the system, barring major system damage, should not be construed as hazard Category I or II.

b. Where hazard Category I or II has been incorrectly assigned, for the above or other reasons, Appendix A documents a reassignment of hazard level.

IV. SAFETY TESTING AND VERIFICATION

A. GENERAL: Safety testing and verification is a process of evaluating and comparing analysis results with the actual operational equipment.

1. Testing and verification was accomplished on the Display Subsystem equipment at the PACMISTESTCEN.

2. Limited verification of the Hydraulic Lifting Unit Subsystem was accomplished at the NAVAIRTESTCEN. Further verification of H/FMEA data, including safety testing, as necessary, will be performed by the NAVAIRENGCEN Test Department (Code 94) at the conclusion of environmental tests under way at this writing.

B. TESTING

1. Testing at PACMISTESTCEN involved the application of overvoltage to the various signal inputs in the Display Console to determine susceptibility to power supply transients from the test simulator assembly.

2. A voltage of 140 VAC at 60 Hz was applied to the following display inputs for a minimum of 5 seconds. No damage occurred:

- a. Range
- b. Ramp Motion
- c. Trim
- d. Rate of Descent
- e. SPN-42 TAS
- f. SPN-42 CLSG
- g. SPN-42 ALT Error
- h. SPN-42 LAT Error
- i. ACLS Aircraft Type (22 inputs)

3. The following display inputs were not subjected to the overvoltage test due to high probability of damage:

- a. MOVLAS (23 inputs) - 6 volts maximum
- b. ACLS Mode (3 inputs) - 32 volts maximum
- c. ACLS Lock-ON - 32 volts maximum
- d. ACLS Wave-Off - 32 volts maximum
- e. LSO Wave-Off - 32 volts maximum

C. VERIFICATION

1. Display Subsystem hardware (display console and auxiliary electronics box) was examined at PACMISTESTCEN with respect to the hazards and failure modes listed in the H/FMEA performed by Ketron, Inc. The more serious hazards were evaluated in terms of severity, probability, and recommended corrective action by direct comparison with operational equipment. PACMISTESTCEN comments have been incorporated along with NAVAIRENGCEN comments in the hazard level I and II summary of Appendix A.

2. Safety verification of the NAVAIRENGCEN designed Hydraulic Lifting Unit Subsystem was limited to a technical evaluation of H/FMEA results, since operational hardware was not yet available. (Hardware safety verification will be conducted by the NAVAIRENGCEN Test Department.) As with the Display Subsystem, the more serious hazards listed in the H/FMEA were evaluated in terms of severity, probability, and recommended corrective action. The evaluation was performed by NAVAIRENGCEN design and safety personnel. Their comments and conclusions for each Category I and II hazard are incorporated in Appendix A.

V. SAFETY PROGRAM RESULTS

A. H/FMEA RESULTS

1. All Category I and II hazards/failure modes identified in the H/FMEA have been resolved as delineated in Appendix A. In general, the hazards/failure modes may be grouped as follows:

a. Twenty of the 29 hazards/failure modes have been reassigned a less severe rating of III or IV. The most common reason for reassignment was the fact that Category I and II was incorrectly assigned to system functional losses. Since the LSO HUD Console System functions as an aid to aircraft recovery, such losses do not in themselves cause personnel injury or major system damage. Therefore, Category I and II does not apply, and reassignment is required.

b. Three of the 29 hazards/failure modes (Items 9, 12, and 23 of Appendix A) will be eliminated or controlled by planned corrective actions.

c. Three of 29 hazards/failure modes (Items 5, 11, and 29 of Appendix A) are considered very unlikely with low overall risk. Corrective action is not warranted.

d. Three of the 29 hazards/failure modes (Items 13, 15, and 16 of Appendix A) are not considered legitimate hazards. No corrective action is required.

2. Corrective action has been taken in the following areas:

a. Overvoltage protection is now specified for the DC power supplies in the auxiliary electronic box. (Appendix A, Item 8.)

b. Hydraulic filter has been changed to reduce the probability of hydraulic pump damage. (Appendix A, Item 13.)

c. Quality acceptance testing has been changed for the relays in the signal junction box and the synchro junction box to provide compatibility with the low current application. (Appendix A, Items 19 and 20.)

B. SAFETY TESTING AND VERIFICATION RESULTS

1. The application of overvoltage to the display console verified that most display inputs can withstand the effects of transformer shorts in the test simulator power supplies. Further protection for overvoltage may be mission desirable but is not required from the standpoint of safety.

2. Safety verification comments relative to both the Display Subsystem and the Hydraulic Lifting Unit Subsystem are incorporated in the Appendix A hazards/failure modes summary.

3. Results of formal safety test and verification of the Hydraulic Lifting Unit Subsystem will be documented in the form of a test report upon completion of the NAVAIRENGCEN (Code 94) test program.

VI. SAFETY PROGRAM CONCLUSIONS AND RECOMMENDATIONS

A. For the most part, the MK 1 MOD 0 LSO HUD Console System has been found well designed with appropriately applied redundancies and fail-safe principles.

B. The corrective actions accomplished and planned as a result of this safety program give reasonable assurance that the MK 1 MOD 0 LSO HUD Console System will be operated and maintained in safety.

C. It is recommended that the planned action identified in Appendix A be implemented:

1. In the technical manual maintenance procedures, direct that removal of the PLAT cathode-ray tube take place in a protected, shop area. Also, advise caution in handling the tube. (Appendix A, Item 1.)

2. In technical manual operating procedures, advise caution with respect to lowering the HUD Console when askew. Ensure planned maintenance system cards include a daily check of HUD askew limit switch operation. (Appendix A, Item 12.)

3. In technical manual maintenance procedures, caution personnel to ensure electrical power is off before performing maintenance on the MOVLAS-HUD Interface Box. (Appendix A, Item 23.)

4. In drawing package, add fillets to rod head weldments. (Appendix A, Item 9.)

It is also recommended that the safety test and verification phase be completed for the Hydraulic Lifting Unit Subsystem, and the resulting recommendations be implemented.

APPENDIX A

LOS HUD Console System H/FMEA
(Ref: NAEC-91-7958):
Hazard Category I and II Summary

LSO HUD Console System H/FMEA (Ref: NAEC-91-7958): Hazard Category I and II Summary

Item No.	H/FMEA		Assign HAZ LEV	Hazard/Failure Mode	Effect	In D M*	Design Changes/Compensating Provisions Rationale for Taking No Action	Planned Action/Compensating Provision
	A-Page No.	Item No.						
1	88	15.0	II	PLAT CRT shatters on removal	Injury to maintenance personnel	In D	HUD console is removable to shop area for CRT replacement under controlled conditions. Hazard level should be III.	Tech Manual to direct CRT removal in shop using caution.
2	93	18.0	II	Wiring/connector faults between console controls and readouts	Malfunction of console indicators/pointers/scale intensity	M	Hazard level should be III (only mission related). Low prob of occurrence.	
3	94	18.0	II	Cable fault/6.3V XFMR opens/control pot wiper liftoff	Loss of control panel backlighting	M	Hazard level III (only mission related). Low prob of occurrence.	
4	100	21.0	II	W223 Cable fault/Pwr loss from Aux Box Pwr supply/1A4 reg bd. fails	Loss of console/ HUD pointer and scale illumination	M	Hazard level III (only mission related)	
5	109	23.0	II	Reticle scale proj lamp shatters when back plate is removed for service.	Injury to maintenance personnel	In D	Heat reflecting glass filter shields lamp. Risk should be no greater than risk typically assumed with lighting equipment.	
6	112	24.0	II	Combiner glass shatters: spherical mirror hits it; tool hits it.	Injury to operating/maintenance personnel.	In D	Combiner glass is safety glass (plastic/glass sandwich). Hazard level should be III.	

*In: Injury to personnel; D: Damage to equipment; M: Mission impairment.

LSO HUD Console System H/FMEA (Ref: NAEC-91-7958): Hazard Category I and II Summary

Item No.	H/FMEA		Assign. HAZ LEV	Hazard/Failure Mode	Effect	In D M*	Design Changes/Compensating Provisions Rationale for Taking No Action	Planned Action/Compensating Provision
	A-Page No.	Item No.						
7	112	24.0	II	Mirror shatters due to slapping caused by failure of hold-down latch	Injury to operating/maintenance personnel.	In D	Hold-down latch is safety latch: disengages only upon lifting for mirror stowage. Hazard level should be III. Also, mirror cannot be raised without positive action by personnel.	
8	118-121	1.0	II	Pwr supply 1/2/3/4 fails; relays/air-flow detector SW/CKT brkr fails/shorted wires at pwr supply output	Console information loss. Some damage to console circuits	M	Hazard level should be III. Partial mission loss only. Also, pwr supplies have been changed to provide overvoltage protection	
9	126	1.1.2.1	II	Rod head weldment cracks for lack of round fillets.	Equipment damage; possible personnel injury.	In D M	Considered extremely improbable.	Filletlets will be added to drawings to affect future production.
10	131	1.1.3	II	Debris between light switch roller and cam forces limit switch over travel	Limit switch damage (LS 1 or LS 2)	D	Hazard level should be III. Damage is minor. Loss of LS 1 or LS 2 does not cause mission loss.	
11	132	1.1.4	II	Cable clamp sharp edges cut through insulation of cables on pedestal leading to console	Electric shock; electric short.	In D M	Hazard exists but is extremely improbable because clamps are actually well designed.	

*In: Injury to personnel; D: Damage to equipment; M: Mission impairment.

LSO HUD Console System H/FMEA (Ref: NAEC-91-7958): Hazard Category I and II Summary

Item No.	H/FMEA		Assign. HAZ LEV	Hazard/Failure Mode	Effect	In D M*	Design Changes/Compensating Provisions Rationale for Taking No Action	Planned Action/Compensating Provision
	A-Page No.	Item No.						
12	141	1.2.7	II	LS 2 limit SW fails enabling HUD down when ASKEW.	Equipment damage; mission loss.	D M		Equipment daily checks will confirm limit SW. operation. Also, op procedures will incl caution re: lowering HUD.
13	142	1.2.8.1	II	Wrong hydraulic filter is specified resulting in inadequate filtering.	Hydraulic pump damage.	D	Disagree with prediction of damage. However, 149 micron filter has been changed to 74 micron.	
14	144	1.2.8.3	II	Vibration causes cracks at lower end of tubing leading to filter.	Loss of hydraulic power. Mission loss.	D M	System has passed shock testing. Also, should be level III since no major damage.	If vibration tests now in progress indicate a weakness, support structure will be incorporated.
15	146	1.2.9.3	III-II	Cable insulation cut by 1.010 and 1.135 dia holes in J-box (hydr pwr pkg).	Electrical shock, mission loss.	In D M	Failure mode is prevented by existence of stuffing tubes.	
16	160	1.3.2.7	II-III	HUD ASKEW SW. fails open. (L4)	System damage and mission loss.	D M	Not a single point failure. Hazard requires secondary failure. Overall probability is extremely low.	

*In: Injury to personnel; D: Damage to equipment; M: Mission impairment

LSO HUD Console System H/FMEA (Ref: NAEC-91-7958): Hazard Category I and II Summary

Item No.	H/FMEA		Assign. HAZ LEV	Hazard/Failure Mode	Effect	In D M*	Design Changes/Compensating Provisions Rationale for Taking No Action	Planned Action/Compensating Provision
	A-Page No.	Item No.						
17	164	1.4.1	I-II	Central J-box relay K2: A or B contacts fail to make; short between NO contacts B.	HUD can not be raised.	M	Manual override enables HUD deployment: Air-motor/pump backup. Should be HAZ level IV.	
	165							
	167							
18	174	1.7.1	I-II	Up-down pendant switch fails shorted	HUD stuck up or down	M	Local control switch in control panel assy on LSO platform provides backup capability. Should be HAZ level IV.	
19	183	1.2	I-II	Signal J-box relays fail to pass current (over-rated contacts) K2, K9, K10, K11, K12	Loss of various console readouts	M	Should be hazard level IV (only mission effects). Also, pre-dominant failure mode has been eliminated: high-current gaul acceptance test has been deleted for these relays.	
	191							
	192							
	193							
	194							
20	198	1.2	I-II	Synchro J-box relays fail to pass current (over-rated contacts) K1 thru K7	Same as above	M	Same as above	
	200							
	202							
	204							
	205							
	207							
	209							

*In: Injury to personnel; D: Damage to equipment; M: Mission impairment.

LSO HUD Console System H/FMEA (Ref: NAEC-91-7958): Hazard Category I and II Summary

Item No.	H/FMEA		Assign. HAZ LEV	Hazard/Failure Mode	Effect	In D M*	Design Changes/Compensating Provisions Rationale for Taking No Action	Planned Action/Compensating Provision
	A-Page No.	Item No.						
21	211 212 213 214	1.3	I	Synchro transmitters jam. Bl thru B4	Erroneous wind angle/velocity, TAS, CAS.	M	Should be HAZ level IV. These transmitters provide static/bias offset and do not operate dynamically as authors thought.	
22	218	1.1	I	Fuse burns out in MOVLAS-HUD inter-face box	Loss of MOVLAS monitor and MOVLAS system	M	Should be HAZ level IV. Fuse does not affect MOVLAS system. Loss of MOVLAS monitor has mild mission impact.	
23	219	1.2	II-III	Power monitor light burns out on MOVLAS-HUD inter-face box.	Electric shock hazard to maintenance personnel who think power is off.	In		Recommended action will be taken: provide cautions in maintenance section of tech manual.
24	224	1.2	I	Cable W221 or conn opens	Loss of Wave-off function (indication).	M	Should be HAZ level IV. Minor mission loss. Extremely improbable.	
25	225	1.5	II-III	Cable W224 or conn opens.	Loss of PLAT monitor function	M	Same as above	
26	225	1.9	I-III	Cable W228 or conn opens.	Obstruction light cannot be energized	In D M	Should be HAZ level III correctable without injury or major system damage.	

*In: Injury to personnel; D: Damage to equipment; M: Mission impairment.

LSO HUD Console System H/FMEA (Ref: NAEC-91-7958): Hazard Category I and II Summary

Item No.	H/FMEA		Assign HAZ LEV	Hazard/Failure Mode	Effect	In D M*	Design Changes/Compensating Provisions Rationale for Taking No Action	Planned Action/Compensating Provision
	A-Page No.	Item No.						
27	226	1.10	I-III	Cables fail or connectors open: W229-239 (11 cables) (Also W222)	Loss of various individual functions or loss of total HUD system function.	M	Should be Hazard level III. These are highly unlikely failures that affect HUD mission only	
	227	thru						
	228	1.20						
28	(224)	1.3	I					
	233	1.1	II	Simulator power supplies 1/2/3 fail causing transients or over voltage to HUD boards/modules during checkout	Induces failures in HUD console boards/modules.	M	Safety testing: signal inputs on most modules have been exposed to 140 VAC for 5 seconds without damage. Hazard level IV.	
29	236	1.3	II-III	Simulator could be dropped inadvertently or single handle could fail.	Damage to simulator, loss of checkout capability.	D	Zero-box handle is judged adequate	

*In: Injury to personnel; D: Damage to equipment; M: Mission impairment

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